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ANALYSIS PROCEDURE FOR THE BOTTOM REFLECTIVITY MEASUREMENTS PRO--ETC(U)

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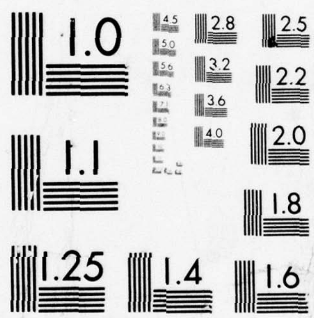

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U. S. NAVY UNDERWATER SOUND LABORATORY
FORT TRUMBULL, NEW LONDON, CONNECTICUT

(6) ANALYSIS PROCEDURE FOR THE BOTTOM REFLECTIVITY MEASUREMENTS PROGRAM,

USL Problem No.
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by

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INTRODUCTION

A bottom reflectivity measurements program has been undertaken to determine the acoustic reflection coefficient for specific areas of ocean bottom as a function of incident angle and frequency. Pulsed single frequency signals are used for these measurements. Deep submerged source and receivers are oriented so that the direct and first-order bottom reflected pulses are separable in time and are not interfered with by the first-order surface reflected pulses. The travel time for the propagation of both the direct and bottom reflected pulses is accurately determined and recorded along with the desired acoustic signal. Since multiple receiving hydrophones are used, the data is also recorded in a multiplexed form. The requirement for efficient and expedient data analysis along with the complexity of the measurement has necessitated the writing of a digital computer program. This program computes the reflection coefficient and angle of incidence for each reception of data. The program corrects for difference in path length, taking into account the depth of the source, receivers, and water, the bottom slope, the velocity gradient and the recorded travel time for each reception.

This memorandum, therefore, discusses (1) the acquisition and processing of the acoustical data; (2) the definitions of the reflection coefficients; (3) the theoretical relationships that properly determine the angle of reflection and reflection coefficient, which are governed by the geometric configuration of the source and receivers and (4) the computer program along with the input and output requirements.

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ACQUISITION AND PROCESSING OF THE ACOUSTIC DATA

It is the purpose of these studies to obtain a measure of the loss that an acoustic signal undergoes upon reflection from the ocean bottom as a function of incident angle and frequency. This can be accomplished by resolving the multipath structure of Figure 1, and comparing the amplitudes of the direct and the first-order bottom reflected pulses, corrected in terms of propagation loss for the difference in path length.

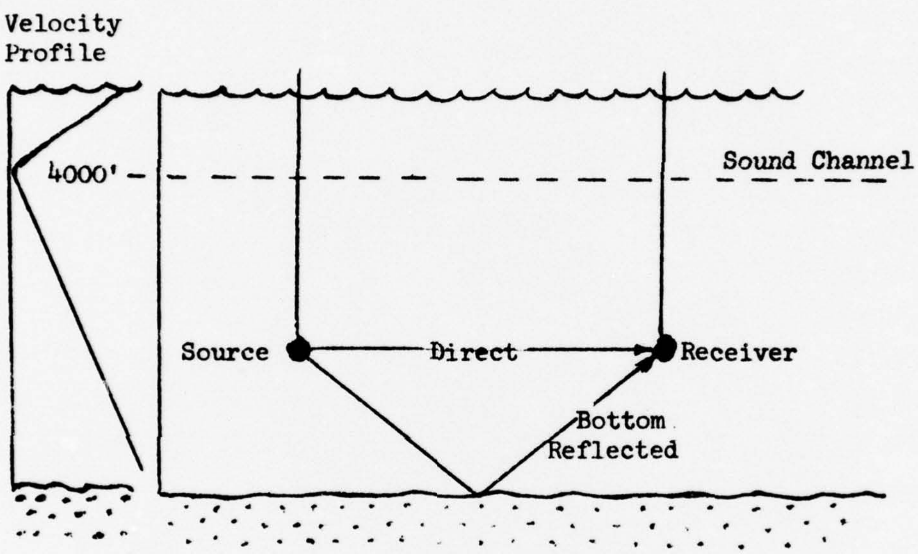

Figure 1 Simplified Ray Paths

The acquisition of the bottom reflectivity data is planned around the availability of an AGOR-type research vessel which has the capability of lowering an acoustic projector to depths in excess of 10,000 feet. This capability necessitated the development of a deep submergence package which contains two free-flooding magnetostrictive scrolls used as projectors. An accurate depth sensing device is also contained on the package. It is, therefore, possible to lower the projector below the sound channel axis. With the receivers positioned below the sound channel axis, the angle of reflection can be calculated with a greater degree of accuracy, and a greater signal-to-noise ratio can be expected for the bottom reflected pulses over the entire range of incident angles.

One of the desired parameters in this study is the angle at which acoustic energy is reflected from the ocean bottom. To obtain this parameter with a sufficient degree of accuracy it is necessary to measure, as closely as possible, the travel time of a transmitted pulse from the projector to the hydrophone over both the direct and first-order bottom reflected paths.

In order to obtain the required measure of travel time, two synchronized Time/Frequency Standards are used. A master is installed aboard the transmitting vessel and a slave at the receiving station.

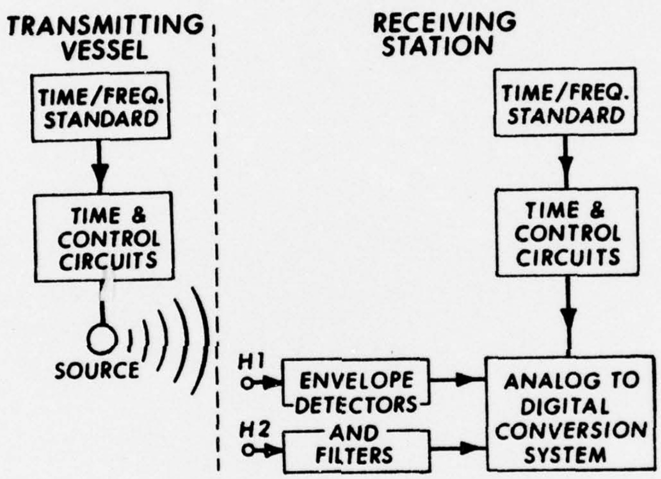

Figure 2 Synchronizing System

The master controls the transmission of the projector while the slave indicates the exact time of the transmission at the receiving station and triggers the timing and control circuits to process the data.

The desired data are composed of pulsed single frequency signals that are received at the hydrophone, amplified, full wave rectified and detected. The resultant signal, the envelope of the received pulse,

is converted into digital form at a rate of 1,000 samples per second. When considering the processing of this type of data via a digital computer, it is mandatory that only the necessary signals for proper analysis be fed into the computer. It is wasteful both in time and money to process signals or noise that is not pertinent to the analysis. It is necessary, therefore, that the processing system be accurately synchronized such that analog signals are converted to digital form only when the desired data are being received; thus a "signal aperture" is established.

When the slave Time/Frequency Standard indicates the exact time of transmission, pulses also generated by the Standard are accumulated in a preset counter until a predetermined preset number is reached. The choice of the preset number is made by an operator who bases his setting of the counter dependent on the position of the previous pulse in the signal aperture. When the preset number is reached, a pulse is generated by the preset counter which is used to trigger an oscilloscope that has its sweep rate set at a value such that the received pulse is encompassed on the oscilloscope face. At the exact time that the oscilloscope is triggered, the Franklin analog-to-digital converter commences processing of the received signals. The Franklin converts the signals for a predetermined period of time, dependent on the pulse length of the received pulse. Thus the pulse is physically observed in the signal aperture as it is simultaneously being converted to digital form. It is necessary, however, to be properly timed and to have all equipment functions properly sequenced before actually recording or converting the desired signals to digital form.

Since the preset counter starts accumulating pulses from the Time/Frequency Standard at the exact time of transmission, and controls the conversion of the received pulses when the preset number is reached, the value of the preset number is proportional to the travel time up to the signal aperture.

$$T_R = \frac{N}{f} \qquad (1)$$

T_R = Travel time

N = Number set into counter

f = Frequency of pulses being fed into counter

The numerals set into the preset counter are recorded through a coding matrix into the ODD records of the digital magnetic tape format used for these measurements.

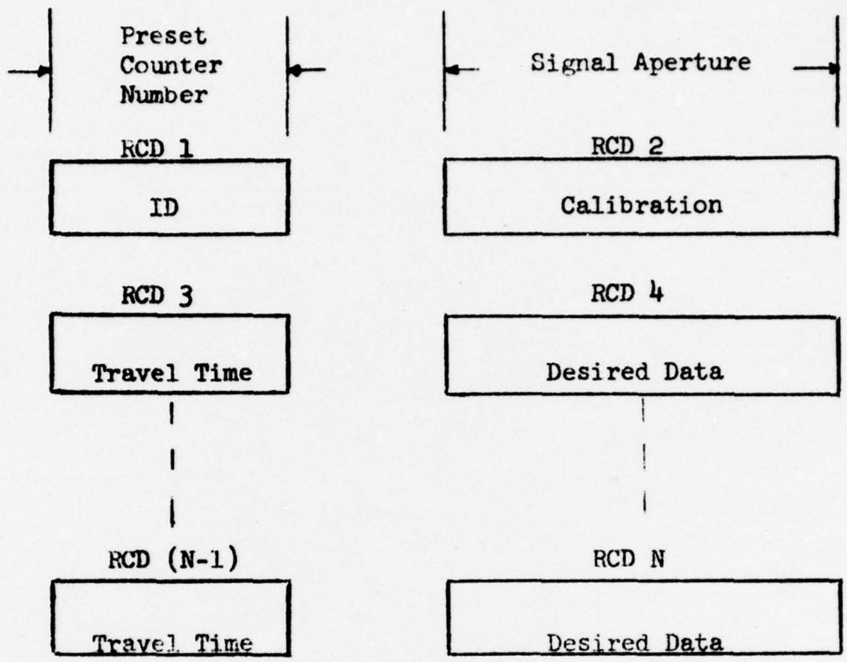

Figure 3 Digital Tape Format

The EVEN records contain the digital equivalent of the received analog pulses. The travel time in the ODD records is in milliseconds and is the measure of the time to the beginning of the signal aperture. To determine the exact travel time to the signal in the aperture it is necessary to count the number of digital samples taken up to the beginning of the received signal. The beginning of the received signal is defined as the point at which a predetermined threshold level is exceeded. The number of digital samples is corrected to its equivalent time in milliseconds and is added to the travel time number in the ODD record. Thus, the exact travel time is preserved along with the data for each reception of data.

The first ODD record (I.D. Record) of the tape format contains ten numbers that are coded for pertinent information about the file of data. It is used as identification of the data, and to cross reference input cards containing parameters used in processing the data through the computer.

The acquisition equipment can be operated in two modes dependent on the separation in time between the direct and reflected pulses. If the pulses are separated by 100 milliseconds, two separate apertures will be used to obtain the data in the EVEN record, one for the direct pulse and one for the reflected pulse. These apertures are controlled by the accumulators of a dual preset counter. Thus the time of conversion is kept to a minimum and only the pertinent data is converted. When this mode is used, there are two sets of 5 binary coded decimal numbers recorded in the ODD record; the first is the travel time to the direct aperture and the second is the travel time to the bottom reflected aperture. If the separation in pulses is under 100 milliseconds, then only one aperture is used, and this aperture contains both the direct and reflected pulses. Therefore,there will be only one set of 5 binary coded decimal numbers recorded in the ODD record indicating the travel time to the signal aperture.

The Franklin analog-to-digital converter system can multiplex input signals. With the sample rate used for these measurements it is possible to have up to five channels multiplexed in the EVEN records. It is also an option of the system to record data from one hydrophone through two channels, one high gain and one low gain (i.e. a 10 db difference in gain between channels). Thus, if the high gain channel overloads, the low gain channel will contain the undistorted data. This increases the dynamic range of the system but must be taken into account when processing the data through the computer.

The operator of the preset controls has the responsibility of establishing a threshold value that will be used as an input parameter to the computer program. This threshold value is constant for a group of pulses, usually associated with a station at which approximately 100 events are recorded, and is based on the observed noise level. Additional input parameters are necessary for the computer program; however, these will be discussed later on in the memorandum.

COEFFICIENTS OF REFLECTION

Bottom reflectivity measurements are performed with the requirement of verifying a theoretical model (reference a) which considers the bottom as a medium made up of a number of plane parallel layers of varying acoustic properties. Absorption of both longitudinal and shear waves has been considered in order to describe the complex reflection and transmission properties of the ocean bottom. It was necessary, therefore, to develop a computer program that would process and present the experimental data in a form suitable for comparison with the predictions of the

model.

To describe the extent to which the amplitude is reduced upon reflection from the ocean bottom it was decided to have the computer program evaluate three different quantities for determing this reduction in amplitude. Considering a pulse made up of a single-frequency sine wave which has been allowed to reach a steady state before it is terminated, and is rectified and detected, it is possible to characterize it by

(1) the time average of the envelope of the signal

$$\frac{1}{T}\int |p| dt$$

(2) the mean-square value of the envelope of the signal

$$\frac{1}{T}\int p^2 dt$$

where p = envelope function of the pressure
T = duration of the pulse

and (3) by the peak pressure which is the maximum amplitude of the steady state signal. By computing each of these quantities for the pulse of the direct arrival and the pulse of the first-order bottom reflected arrival and finding their ratio, three separate coefficients are obtained.

Of the three reflection coefficients which this program provides, the one based on peak amplitude is currently of greatest interest, since it can be interpreted as the ratio of steady-state amplitude of a continuous signal before and after reflection, and can thus be compared with the predictions of an existing model (reference a). This model is based on a steady-state solution for a single frequency plane wave incident on a multi-layered bottom. Thus, a comparison using the measured peak coefficient can be made as long as the bottom structure used in the model takes into account the effective penetration of the pulse up to the time at which the maximum occurs. That is, the maximum amplitude, occuring "t" milliseconds from the beginning of the pulse, can be regarded as the maximum amplitude of a continuous wave containing components reflected at only those interfaces which the pulse has traversed in "t/2" milliseconds.

At present, USL Computer Program No. 0134 based on this model does not provide theoretical values for the other two coefficients. However, it is felt that these two quantities are both legitimate measures of the ocean bottom's reflective properties. The time integral of the envelope

of the signal divided by the duration of the pulse gives us the average amplitude of the pulse. The time integral of the square of the envelope divided by the duration of the pulse is proportional to the energy flux, that is, the energy per unit area per unit time. Thus, the ratio between the bottom reflected and incident values of each of these quantities indicates a reduction in the average acoustic pressure for one case, and in the flow of energy for the other case.

THEORETICAL RELATIONSHIPS

Unequal path lengths for the direct and bottom reflected acoustic pulses required that corrections be applied to the ratios so that they represent the ratios which would actually be measured at the water-sediment boundary. Furthermore, the angle of incidence at the bottom was required for each transmission, so that a method of computing this angle with reasonable accuracy had to be devised. The following assumptions and derivations served as the basis for the mathematical relationships used in the computer program.

ANGLE

The chief assumption here is that a constant velocity gradient exists in every part of the medium which is traversed by the rays we are considering. This assumption is reasonable, provided the source and receiver are both located below the axis of the permanent sound channel. Figure 4 represents the geometry of the ray paths under such conditions. (See top of Page 9)

The approach used here is similar to that in reference (b), except that we require an explicit solution of the angle α without knowledge of the source angle. From Snell's Law, it can be shown that the path of an acoustic ray in a medium having a single constant gradient is the arc of a circle having the form

$$(x - x_0)^2 + (y - y_0)^2 = \frac{V_s^2}{g^2} \sec^2 \theta \qquad (2)$$

where V_s = sound velocity at the source,

g = the velocity gradient, a constant,

θ_s = the source angle of the ray

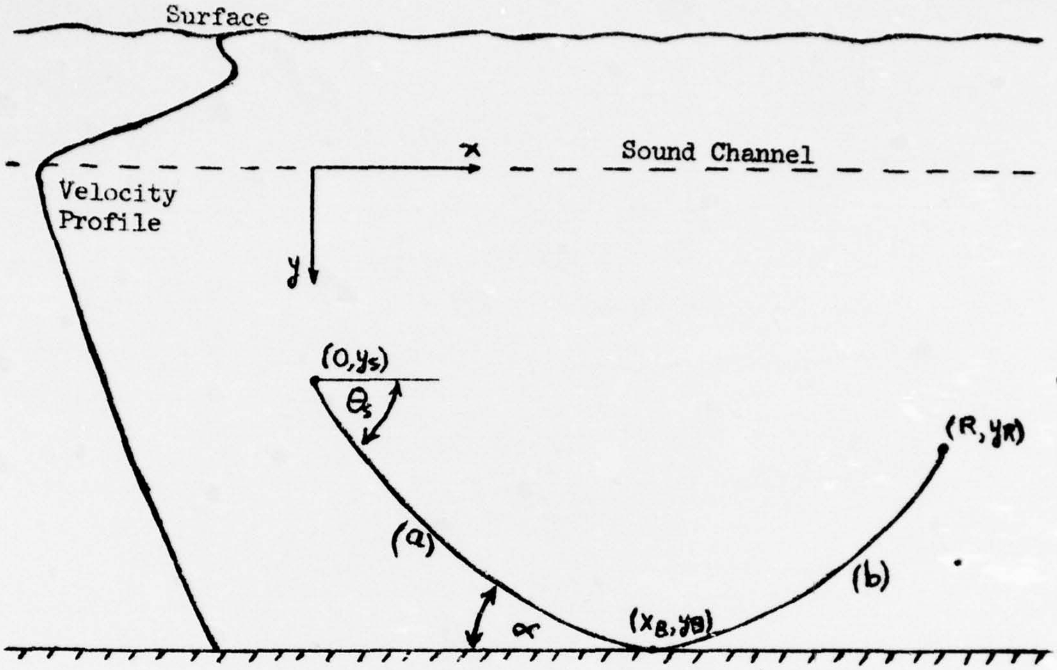

Figure 4 Geometry of Ray Paths

Specifically, choosing the coordinate system as in Figure 4, we have

$$(x-x_0)^2+(y-y_0)^2=\frac{V_S^2}{g^2}\sec^2\theta_S \tag{3}$$

for path (a), and

$$(x-x_1)^2+(y-y_1)^2=\frac{V_B^2}{g^2}\sec^2\alpha \tag{4}$$

for path (b).

Equation (3) can be expressed in terms of α instead of θ_S by applying Snell's Law:

$$V_S\sec\theta_S=V_B\sec\alpha. \tag{5}$$

Thus, equation (3) can be written

$$(x-x_0)^2+(y-y_0)^2=\frac{V_B^2}{g^2}\sec^2\alpha. \tag{6}$$

It is now possible to obtain an expression for the angle α from equations (4) and (6) in terms of known quantities.

Differentiating (4) and (6) we get

$$\frac{dy}{dx} = -\frac{x-x_1}{y-y_1} \tag{7}$$

and

$$\frac{dy}{dx} = -\frac{x-x_0}{y-y_0}\,. \tag{8}$$

At $x=x_B$, $y=y_B$, these are related to $\tan\alpha$ as follows:

$$-\frac{x_B-x_1}{y_B-y_1} = -\tan\alpha \tag{9}$$

and

$$-\frac{x_B-x_0}{y_B-y_0} = \tan\alpha\,, \tag{10}$$

where the sign of the tangent is determined by the quadrant in which the ray lies. Utilizing the fact that y_0 and y_1 represent the depth at which the velocity is zero, we have

$$g = \frac{V_B-0}{y_B-y_0} \tag{11}$$

and

$$g = \frac{V_B-0}{y_B-y_1}\,, \tag{12}$$

from which we obtain

$$y_B-y_0 = y_B-y_1 = \frac{V_B}{g}\,. \tag{13}$$

Substituting this in equations (9) and (10) and eliminating X_B, we obtain

$$x_0 = x_1 + \frac{2V_B}{g}\tan\alpha\,. \tag{14}$$

We now need two more equations in order to solve for $\tan\alpha$. Consider equation (6); when $x = o$, $y = y_s$. Thus

$$x_0^2 = \frac{V_B^2}{g^2}\sec^2\alpha - (y_s-y_0)^2, \tag{15}$$

But

$$g = \frac{V_s-0}{y_s-y_0}\,; \tag{16}$$

therefore,

$$(y_S - y_0)^2 = \frac{V_S^2}{g^2} , \tag{17}$$

and thus equation (15) becomes

$$X_0 = \pm \sqrt{\frac{V_B^2}{g^2} \sec^2\alpha - \frac{V_S^2}{g^2}} . \tag{18}$$

When $x = R$, $y = y_R$; therefore, equation (4) becomes

$$(R - x_1)^2 + (y_R - y_1)^2 = \frac{V_B^2}{g^2} \sec^2\alpha . \tag{19}$$

Solving for $(R - x_1)$, we obtain

$$R - X_1 = \pm \sqrt{\frac{V_B^2}{g^2} \sec^2\alpha - (y_R - y_1)^2} . \tag{20}$$

But

$$g = \frac{V_R - 0}{y_R - y_1} ; \tag{21}$$

thus

$$(y_R - y_1)^2 = \frac{V_R^2}{g^2} , \tag{22}$$

and equation (20) becomes

$$X_1 = R \mp \sqrt{\frac{V_B^2}{g^2} \sec^2\alpha - \frac{V_R^2}{g^2}} . \tag{23}$$

Combining equations (14) and (23), we obtain

$$X_0 = R \mp \sqrt{\frac{V_B^2}{g^2} \sec^2\alpha - \frac{V_R^2}{g^2}} + \frac{2 V_B}{g} \tan\alpha . \tag{24}$$

Equating (24) to (18), we get

$$\sqrt{\frac{V_B^2}{g^2} \sec^2\alpha - \frac{V_S^2}{g^2}} = R \mp \sqrt{\frac{V_B^2}{g^2} \sec^2\alpha - \frac{V_R^2}{g^2}} + 2 \frac{V_B}{g} \tan\alpha . \tag{25}$$

We can ignore the signs of the radicals, since these quantities will all be squared in the process of solving for $\tan \alpha$.

The result of squaring equation (25) twice and combining terms (an operation which is a little too lengthy to be presented here) is the cubic

$$A \tan^3\alpha + B \tan^2\alpha + C \tan\alpha + D = 0 \tag{26}$$

where

$$A = -16 V_B^3 g R$$

$$B = 4V_B^2\left[4V_B^2 - 5g^2R^2 - 2(V_S^2 + V_R^2)\right]$$

$$C = 8V_B gR\left[2V_B^2 - (g^2R^2 + V_S^2 + V_R^2)\right]$$

$$D = -\left[(V_S^2 - V_R^2)^2 + 2g^2R^2(V_S^2 + V_R^2) - g^2R^2(4V_B^2 - g^2R^2)\right].$$

Thus, if the gradient, range and velocities at the source, receiver, and bottom are known, the reflection angle can be calculated.

RANGE

Although the velocities and depths can be measured with reasonable accuracy, horizontal range from source to receiver is difficult to obtain. Uncertainty in the horizontal position of a deeply submerged package relative to the ship, due to the catenary which the cable assumes, increases the error introduced in ship positioning. Since acoustic travel time can be measured fairly precisely, it was felt that range computed from travel time, average velocity and depth would be sufficiently accurate.

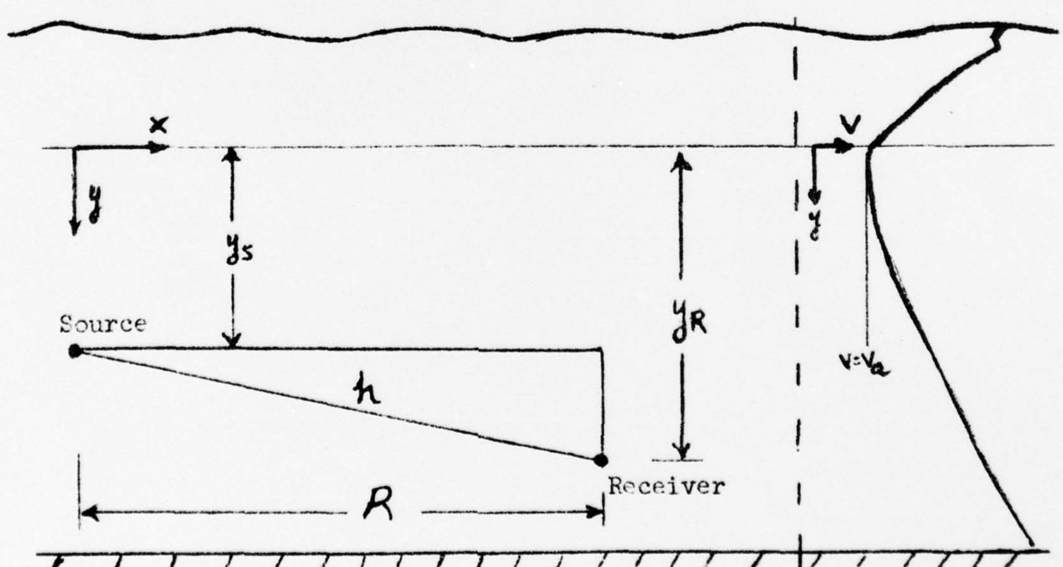

Figure 5 Geometry for Determining Range

Consider Figure 5. Assuming a single, constant gradient below the axis of the permanent sound channel (the point y = o), the average velocity is readily computed from the relation

$$\overline{V} = \overline{(gy + V_a)} = \frac{g}{2}(y_R + y_s). \tag{27}$$

Thus, from the straight line geometry of Figure 5,

$$R = \sqrt{h^2 - (y_R - y_s)^2}\ , \tag{28}$$

Making use of the travel time t over the direct path h, which is directly measured for each transmission, and the average velocity over h as computed from equation (27), we can determine the range from

$$R = \sqrt{\left[\frac{g}{2}(y_R + y_s) + V_a\right]^2 t^2 - (y_R - y_s)^2} \tag{29}$$

PATH LENGTH

Since the results of this program are to be compared with the predictions of a model which does not consider loss due to propagation in the water, corrections for the path lengths of the direct and bottom reflected arrivals must be applied to the measured reflection coefficients. In general, the path length of a ray in a medium having a constant velocity gradient is given by (Reference c)

$$S_n = \left(\frac{\pi V_x}{180 g_n}\right)\left[\cos^{-1}\left(\frac{V_n}{V_x}\right) - \cos^{-1}\left(\frac{V_{n+1}}{V_x}\right)\right], \tag{30}$$

where

n = an integer which indicates the layer in which the velocity gradient is constant,
g_n = the value of the gradient in the layer,
V_n = the velocity at the upper boundary
V_{n+1} = the velocity at the lower boundary
V_x = the velocity at which the ray vertexes.

The inverse cosines in the brackets must be expressed in degrees. The vertex velocity can be determined if the velocity and angle of inclination of any point on the ray is known. From Snell's Law,

$$\frac{V}{\cos\theta} = \frac{V_x}{\cos 0^\circ} = V_x\ . \tag{31}$$

Thus, V_x for both sections of the bottom path can be calculated, since

the velocity at the bottom is known, and the angle which the ray makes with the horizontal, which is just the grazing angle α , can be computed. However, since no angle is known on the direct path, the vertex velocity is unknown, and this path length can only be approximated by the straight line h in Figure 5 and must be computed from

$$h = \bar{v}t \tag{32}$$

where t is the travel time of the direct arrival.

PROPAGATION LOSS CORRECTION

As was mentioned earlier, the reflected and direct amplitudes must be corrected for differences in path length in order that their ratio accurately represents the reflection coefficient. The appropriate corrections are made to the ratios themselves by application of a multiplicative factor derived from the relation given in reference (d) (Eq. 3A-5)

$$\frac{I_2}{I_1} = \left(\frac{S_2}{S_1}\right)^n \left(10^{0.1}\right)^{-a(S_2-S_1)} \tag{33}$$

where

I_1 = intensity at the beginning of the path,
I_2 = intensity at the end of the path,
S_1 = distance from the source to the point at which I_1 is measured,
S_2 = distance from the source to the point at which I_2 is measured,
n = an integer to be determined by the type of spreading involved,
a = the attenuation coefficient .

This is the antilog of the familiar propagation loss equation. For our purposes, spherical spreading (n= -2) and an attenuation coefficient given by

$$a = 0.01 f^2 \tag{34}$$

were assumed.

Since the reflection coefficients are ratios of acoustic pressures, we

must take the square root of both sides of the above equation, which gives us the ratio of acoustic pressures measured at two points along the path. Thus, if a and b are two points on a ray path, then

$$\frac{P_a}{P_b} = \frac{S_b}{S_a} 10^{-0.0005 f^2 (S_b - S_a)} . \tag{35}$$

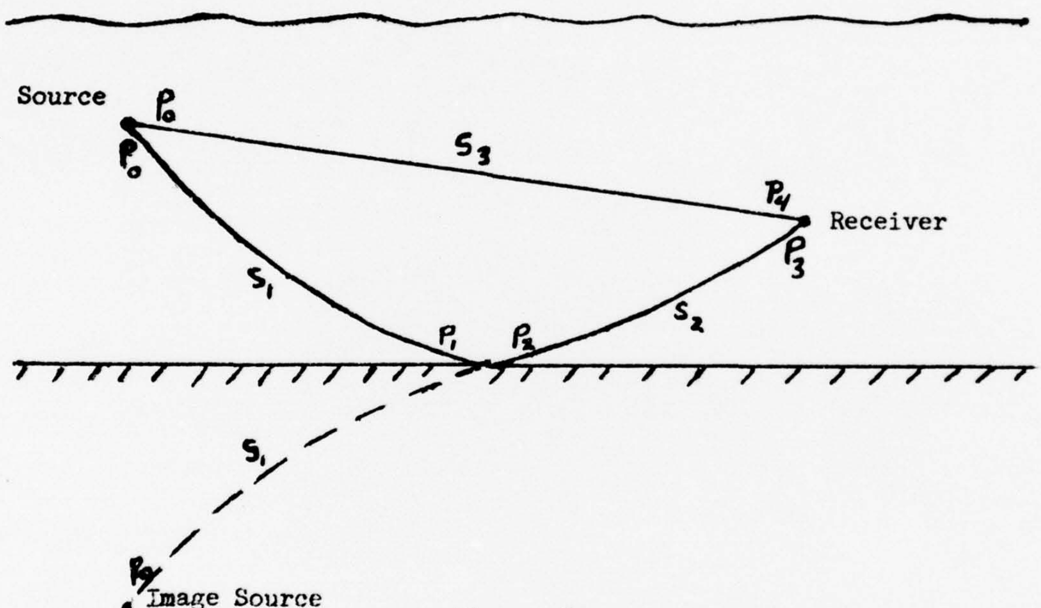

Figure 6
Identification of Pressures and Paths
Used in Propagation Loss Equations

Consider Fig. 6. The P_i represent the acoustic pressure at various points on the rays. The ratio we desire is P_2/P_1, and the uncorrected coefficient is the ratio of the bottom reflected to direct peak amplitude, or P_3/P_4. We must, therefore, determine a constant k, such that

$$\frac{P_2}{P_1} = K \frac{P_3}{P_4} . \tag{36}$$

Using equation (35), we obtain the following relations between the pressure amplitudes at the various points:

$$\frac{P_1}{P_0} = \frac{S_0}{S_1} 10^{-0.0005 f^2 (S_1 - S_0)} = C_1 , \qquad (37\text{-a})$$

$$\frac{P_3}{P_2} = \frac{S_1}{S_1 + S_2} 10^{-0.0005 f^2 (S_2)} = C_2 , \qquad (37\text{-b})$$

$$\frac{P_4}{P_0} = \frac{S_0}{S_3} 10^{-0.0005 f^2 (S_3 - S_0)} = C_3 . \qquad (37\text{-c})$$

Combining (37-a) and (37-b), we get

$$\frac{P_2}{P_1} = \frac{P_3}{C_1 C_2 P_0} . \qquad (38)$$

Substituting P_0 in (37-c) into (38), we obtain

$$\frac{P_2}{P_1} = \frac{C_3}{C_1 C_2} \frac{P_3}{P_4} . \qquad (39)$$

Thus, by computing the ratio C_3/C_1C_2 from equation (37), in which frequency has units of kc/sec and the path lengths S_i, expressed in kyd, are determined from equations (30) and (32), the corrected reflection can be obtained. It should be noted that S_0, which corresponds to the distance between the source and the point at which the acoustic pressure "at the source" is measured is taken to be one yard by convention, to prevent indeterminate terms from arising.

COMPUTER PROGRAM DESCRIPTION

USL Computer Program No. 0289 processes observed data for the determination of reflection coefficients.

The input is in the form of digitized magnetic tape (Datrac), and Hollerith cards as detailed in Table I. Two cards are required for each file of information on Datrac Tape. The tape consists of up to three files, the even records of which contain voltage readings to three significant figures proportional to the acoustic pressure. The first odd record in each file is an identification word which is compared with the corresponding identification word from cards. The first even record

in each file is calibration data and is used to obtain a multiplicative constant by which low gain data are modified to correspond to high gain information, when applicable. Subsequent odd records contain information as to the time (in milliseconds) until the aperture for the direct pulse information begins, and possibly the time to the start of the bottom reception aperture. If only one value appears in the odd record, it is assumed that the signal was recorded continuously, after the beginning of the direct aperture, through the bottom reception. The even records, after the first for each file, contain reception data for direct and bottom reflection. The program allows for up to five channels of information from these even records. Each channel may pertain to one hydrophone, or two channels may be allocated to one hydrophone so that high and low gain data are present. If the high and low gain condition exists, the program has an alternative means of getting results when the maximum reception voltage is observed in the high gain channel. It is assumed that calibration data will be present in the second record of each file even if the high and low gain option is not being used.

The program has two main divisions. The first pertains to obtaining and processing all the necessary data from tape, and the second deals with the computation and printing of the desired output results. The separation of these two major parts is at statement number 200 in the program.

In the second part of the program is a subroutine for solving a specific third degree polynomial. The polynomial is in terms of tangent α where α is the angle of reflection that the acoustic ray makes with the bottom. The subroutine uses the Newton-Raphson method for obtaining one root of the cubic equation. The other roots are obtained by reducing the polynomial one degree and solving the resulting equation by the quadratic formula. The first root obtained is accepted if the remaining roots are imaginary, or if the remaining roots lay outside the range of $+2^{\circ}$ to $+85^{\circ}$. If one of these conditions is not met, a message will be printed by the computer. A starting value of alpha is part of the input data for the program and is necessary for the operation of this iterative process. Experience with the data determining the coefficients of these polynomials has indicated that a choice of angles between $+60^{\circ}$ and $+70^{\circ}$ will insure convergence if the data affecting direct travel time are correctly given to the program.

In the first part of the program semi-fixed criteria are used to determine when the direct and bottom pulses have begun and ended. In the case of the direct pulse, ten consecutive samples above threshold are sought to determine the start of the pulse, and five consecutive samples below the threshold voltage indicate the end of the pulse.

The bottom reception starts when ten consecutive samples appear above the threshold voltage. The end occurs when one sample falls below or equals the threshold voltage. However, if subsequently, five consecutive pulses exceed the threshold voltage, then all the samples which occurred since the previous termination are considered as part of the bottom reception. In addition, the bottom reception includes all those that continue to stay above threshold for a predetermined time or until the samples again equal or fall below threshold, whichever comes first.

The Fortran Program is available as Appendix A. Also, samples of the printed output are contained in Figures 7 and 8. Figure 7 represents the output when sense switch one is down, and Figure 8 covers the print-out with sense switch two down. These options may be exercised singly or jointly. With sense switch two down, all the calculated data are put on a master tape togeter with the pulse values above threshold and all input information. This can then be used for statistical studies done by other specially written programs.

SUMMARY

This memorandum discusses an integrated system for the acquisition, processing and analysis of Bottom Reflectivity Data. A technique has has been successfully adapted and favorable results are presently being obtained. The acquisition of data is semi-automatic, once sychronization is established, and the data is obtained in digital form for computer processing. The computer program also discussed has been written based on an analysis procedure outlined in this memorandum. This program determines reflection coefficients as a function of angle of incidence. The analysis procedure and the output requirements of the program are such that an effective comparison of the results can be made with predicted theoretical results. These results are obtained from a multi-layered theoretical model of the bottom via a computer program where the input parameters are determined from analyses of sediment cores obtained at the same area of ocean bottom where the acoustical measurements were made.

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LIST OF REFERENCES

(a) M. C. Karamargin, "A Treatment of Acoustic Plane Wave Reflections From an Absorbing Multi-layered Liquid and Solid Bottom", USL Technical Memorandum No. 913-91-62, 16 July 1962.

(b) R. L. Martin, "Determination of the Angle at Which a Received Signal is Reflected From the Bottom", USL Technical Memorandum 1170-115-59, 5 Jan 1959

(c) L. Mellberg, "Path Length of a Sound Ray in a Multi-layered Medium", USL Technical Memorandum No. 911-81-62, 11 Sept 1962.

(d) J. W. Horton, FUNDAMENTALS OF SONAR, United States Naval Institute, Anapolis, Maryland, 1957.

TABLE I

Input Card Format for Program No. 0289

Card No.	Cols.	Decimal Point Location for Floating Point No's	Contents
1	1-3	Fixed Integer	IBM Tape Number (Datrac Tape)
	4	Fixed Integer	Datrac Tape File Number
	5-14	Fixed Integer	Identification word used to check with Datrac Tape Identification
	15	Alphabetic	Letter giving the Event identification
	16-18	XXX.	Pulse width, in milliseconds
	19-20	X.X	Frequency, in kilocycles
	21	Fixed Integer	Channels per hydrophone (1 or 2)
	22	Fixed Integer	Number of channels being used
	23-24	XX.	Fixed time delay, in milliseconds
	25-27	Fixed Integer	Number of receptions per file of Datrac Tape
	28-31	Fixed Integer	Number of Words per even record of Datrac Tape
	32-34	XX.X	Approximate Range, in kyds
	35-37	XX.X	Approximate Angle of Incidence in Degrees

TABLE I CONTINUED

Input Card Format for Program No. 0289

Card No.	Cols.	Decimal Point Location for Floating Point No's	Contents
1	36-39	X.X	Coefficient of the number of samples in the Direct Pulse. The product of these values is used to determine the period in which a Bottom Pulse is sought.
	40-44	$\pm$.XXXX	Gradient, in feet/sec-feet
	45-47	.XXX	Threshold Voltage, in volts
	48-51	XXXX.	Velocity (ft/sec) at sound channel Axis
	52-55	XXXX.	Sound Channel Axis Depth, in feet
	56-60	XXXXX.	Bottom Depth, in feet
	61-65	XXXXX.	Source Depth, in feet
	66-70	XXXXX.	First Receiver Depth, in feet
	1-5	XXXXX.	Second Receiver Depth, in feet, if present
	6-10	XXXXX.	Third Receiver Depth, in feet, if present
	11-15	XXXXX.	Fourth Receiver Depth, in feet, if present
	16-20	XXXXX.	Fifth Receiver Depth, in feet, if present
	21-30	XXXXXXX.XXX	Digital Sampling Rate (Samples/Msc)

PROGRAM OUTPUT SENSE SWITCH ONE DOWN

IBM TAPE NO. 285 FILE NO. 1

ID WORD	APPROX. RANGE	EVENT	FREQ.	PULSE WIDTH	THRES. VOLT.	SOURCE DEPTH	REC. DEPTHS
1080354011	1.0 KYDS.	A	1.0KC	10.MSC.	0.015 VOLTS	2925.FT.	3862.FT. 4165.

IBM TAPE NO. 285 FILE NO. 1 RECEPTION NO. 1 CHANNEL NO. 2

PEAK COMPUTATIONS

DIRECT PEAK	REFLECTED PEAK	DIRECT PRESS./SOURCE PRESS.	REFLECTED/DIRECT
1.064	0.091	0.75780631E-03	0.110

AVERAGE COMPUTATIONS

DIRECT SUM	DIRECT AVERAGE	BOTTOM SUM 1	BOTTOM SUM TOTAL	BOTTOM AVERAGE	BOTTOM AV./DIRECT AV.
11.680	0.433	1.459	1.459	0.049	0.145

ENERGY FLUX COMPUTATIONS

MEAN SQUARED DIRECT	SUM OF BOTTOM 1 SQUARED	MEAN SQUARED BOTTOM	BOTTOM/DIRECT
0.334	0.094	0.003	0.017

MISCELLANEOUS

90-ALPHA	BOT. SAMPLES	DIR. SAMPLES	FIRST BOT. SAMPLES	DIR. TRAVEL	BOT. TRAVEL	COMP. RANGE
48.98DEG.	30	27	30	0.810 SEC.	1.045 SEC.	1.280 KYD.

IBM TAPE NO. 285 FILE NO. 1 RECEPTION NO. 1 CHANNEL NO. 3

PEAK COMPUTATIONS

DIRECT PEAK	REFLECTED PEAK	DIRECT PRESS./SOURCE PRESS.	REFLECTED/DIRECT
0.896	0.092	0.74205969E-03	0.125

AVERAGE COMPUTATIONS

DIRECT SUM	DIRECT AVERAGE	BOTTOM SUM 1	BOTTOM SUM TOTAL	BOTTOM AVERAGE	BOTTOM AV./DIRECT AV.
10.437	0.417	1.741	1.741	0.050	0.145

ENERGY FLUX COMPUTATIONS

MEAN SQUARED DIRECT	SUM OF BOTTOM 1 SQUARED	MEAN SQUARED BOTTOM	BOTTOM/DIRECT
0.274	0.113	0.003	0.024

MISCELLANEOUS

90-ALPHA	BOT SAMPLES	DIR. SAMPLES	FIRST BOT. SAMPLES	DIR. TRAVEL	BOT. TRAVEL	COMP. RANGE
51.67DEG.	35	25	35	0.827 SEC.	1.006 SEC.	1.280 KYD.

FIGURE 7

PROGRAM OUTPUT SENSE SWITCH TWO DOWN

DATRAC TAPE			MASTER TAPE	
NO.	FILE	RECEPTIONS	NO.	TOTAL RECORDS
218	1	15	338	145

EVENT	ID NUMBER
A	1060132134

HYDROPHONE	DEPTH IN	90-ALPHA (DEG)	
NUMBER	FEET	MAX.	MIN.
1	3640.0	52.640	52.308
2	3752.0	53.165	52.777

FIGURE 8

```
C       DETERMINATION OF REFLECTION COEFFICIENTS FROM OBSERVED DATA    0289
C
S  ION OCT 016060606060
S  IBB OCT 226060606060
S  ICC OCT 236060606060
S  IDD OCT 246060606060
S  IEE OCT 256060606060
S  IZZ OCT 716060606060
        DIMENSION ID(2),AP(2),CALN(5),CALD(5),WD(5,100),DR(5),YR(5),VR(5),
       1          IDUMP(9),NSD(5)     ,NSB(5),TTD(5),TTB(5),LD(5),LB(5),
       2          SUMA(5),SUMS(5),WMAX(5),SUMB(5),SUMBS(5),BMAX(5),SVIX(5)
       3          ,NSB2(5),SVI(5),TAP(180),TMP(180),AMNA(5),AMXA(5)
        READ 14,IRT,IFT,MIT
S       CLA IRT
S       TZE *1
        DO 1111 L=1,IRT
S       RTD 1
 1111   CONTINUE
S       IOD
    1   READ INPUT TAPE 3,5,IBM,IFILE,ID3,ID4,EVENT,PW,FREQ,IGAIN,MULT,X,
       1      NRECF,IWPR,APR,AANG,FAC,G,TH,VA,DA,DB,DS,DR(1)
        READ INPUT TAPE 3,6 ,(DR(I),I=2,5),PM
        DO 2 I=1,5
        AMNA(I)=90.0
    2   CALN(I)=0.0
    3   FORMAT (15HDATRAC TAPE NO.,I5,5X8HFILE NO.,I3,5X15HMASTER TAPE NO.
       1,A5/46HRECORDS ON MASTER TAPE TO START OF DATRAC FILE,I6)
        IDUMP(6)=IDUMP(6)+2
    5   FORMAT (I3,I1,2A5,A1,F3.0,F2.1,2I1,F2.0,I3,I4,2F3.1,F2.1,F5.4,F3.3
       1,2F4.0,3F5.0)
    6   FORMAT (4F5.0,F10.3)
S       CLA G
S       TZE *12
        PUNCH 3,IBM,IFILE,MIT,IRT
        CALL DATSP (7,ID(1),0,1,0,0,0,0,0)
        DO 666 I=1,2000
S       STZ CALN(1)
  666   CONTINUE
        NH=MULT/IGAIN
S       CAL ID3
S       ARS 6
S       SUB ID(1)
S       TZE *10
    7   PRINT 8
    8   FORMAT(38H ID ERROR, CHECK INPUT CARDS WITH TAPE)
        PAUSE 7007
S  10   CAL ID4
S       ARS 6
S       SUB ID(2)
S       TZE *15
S       TRA *7
   12   NRECF=(NRECF*2)+3
        DO 13 J=1,NRECF
S       RTD 7
S       IOD
        IDUMP(6)=IDUMP(6)+1
   13   CONTINUE
```

```
   14 FORMAT (2I5.A5)
      IDUMP(6)=IDUMP(6)-2
      GO TO 1
   15 IF (SENSE SWITCH 1) 16,21
   16 PRINT 20,IBM,IFILE,ID3,ID4,APR,EVENT,FREQ,PW,TH,DS,(DR(I),I=1,NH)
   20 FORMAT (1H1/1H0,18X12HIBM TAPE NO.,I4,9X8HFILE NO.,I2/1H0,1X91HID
     1WORD    APPROX. RANGE  EVENT  FREQ.  PULSE WIDTH  THRES. VOLT.  SOU
     2RCE DEPTH  REC. DEPTHS/1X,2A5,3X,F5.1,5HKYDS.,5X,A1,3X,F4.1,2HKC,
     33X,F5.0,4HMSC.,3X,F5.3,6H VOLTS,5X,F6.0,3HFT.,3X,F7.0,3HFT./82X,
     4F7.0/82X,F7.0/82X,F7.0/82X,F7.0)
   21 TH=10.*TH
      YS=DS-DA
      YB=DB-DA
      VS=YS*G+VA
      VB=YB*G+VA
      IM=1
      IE=0
      NCA=100
      I5=IWPR-(100*MULT)
S     TPL *38
      NCA=IWPR/MULT
      IW4=0
      IREM=0
S     TRA *39
   38 IW4=IWPR/(MULT*100)
      IREM=(IWPR-IW4*MULT*100)/MULT
   39 ISAVE7=IW4
      ISAVE8=IREM
      ISAVE9=NCA
C
C     USE CALIBRATION DATA
C
      CALL DATSP (7,WD(1,1),0.0,NCA,MULT,5,1,0)
      IF (IGAIN-1) 46,46,40
   40 DR(4)=DR(2)
      DR(3)=DR(2)
      DR(2)=DR(1)
      DO 45 I=1,MULT,IGAIN
      CALN(I)=0.0
      CALD(I)=0.0
      K=I+1
      DO 44 J=6,15
      CALN(I)=CALN(I)+WD(I,J)
      CALD(I)=CALD(I)+WD(K,J)
   44 CONTINUE
      CALN(K)=CALN(I)/CALD(I)
   45 CONTINUE
   46 IF (SENSE SWITCH 2) 446,47
  446 WRITE OUTPUT TAPE 1,447,IBM,IFILE,ION,NH,ID3,ID4,APR,EVENT,FREQ,
     1          PW,TH,DS,(DR(I),I=1,5),CALN(2),CALN(4)
      IRT=IRT+1
  447 FORMAT (I3,I1,5XA1,I1,2A5,F4.1,A1,F3.1,F4.0,F4.2,F5.0,5F6.0,2E15.8
     1)
   47 DO 48 J=1,MULT
      YR(J)=DR(J)-DA
   48 VR(J)=YR(J)*G+VA
   50 AP(1)=0.0
```

```
      AP(2)=0.0
      NSB1=0
      LT-1
      LMN=0
      LMN1=0
C
C     OBTAIN APERTURES
C
      I2=1
      CALL DATSP (7,AP(1),0,0,1,2,2,1,1)
      IE=IE+1
      IDUMP(6)=IDUMP(6)+2
      IVT=IRT
S  63 CLA AP(2)
S     TZE *255
S     CLA AP(1)
S     TZE *65
S     TRA *75
   65 AP(1)=AP(2)
      AP(2)=0.0
   75 CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
C
C     SEARCH FOR START OF DIRECT PULSE
C
      TV=TH
      I=IM
      ICD=1
      NS=0
      NTV=0
      DO 81 J=1,100
      NS=NS+1
      IF (WD(I,J)-TV) 80,80,79
   79 NTV=NTV+1
      IF (NTV-10) 81,83,83
   80 NTV=0
   81 CONTINUE
      JFK=JFK+1
      IF (JFK-3) 8000,8000,9000
 8000 BACKSPACE 7
      GO TO 75
 9000 SUMA(I)=0.0
      IF (SENSE SWITCH 1) 9001,190
 9001 PRINT 82,I
   82 FORMAT (1H0,11HCHANNEL NO.,I3,47H SHOWS NO SIGNAL ABOVE THRESHOLD
     1IN 100 SAMPLES)
      GO TO 190
   83 NS=NS-10
      JFK=0
      TTD(I)=NS
      TTD(I)=TTD(I)/PM+AP(1)+X
      I1=NS+1
      LD(I)=0
      LB(I)=0
   84 SUMA(I)=0.0
      SUMS(I)=0.0
      NS1=0
      NTV=0
```

```
      NSD(I)=0
      I5=0
      SUMBX=0.0
      SUMBSX=0.0
      WMAX(I)=WD(I,I1)
      LT1=0
C
C     START OF DIRECT PULSE
C
   86 DO 93 J=I1,NCA
      IF (WD(I,J)-9.99) 87,94,94
   87 IF (TV-WD(I,J)) 89,88,88
   88 NTV=NTV+1
      SUMBX=SUMBX+WD(I,J)
      SUMBSX=SUMBSX+(WD(I,J)**2)
      TMP(LT)=WD(I,J)
      LT=LT+1
      IF (NTV-5) 92,97,97
   89 IF (WD(I,J)-WMAX(I)) 91,91,90
   90 WMAX(I)=WD(I,J)
   91 SUMA(I)=SUMA(I)+WD(I,J)+SUMBX
      SUMS(I)=SUMS(I)+(WD(I,J)**2)+SUMBSX
S     CLA SUMBX
S     TZE *992
      DO 991 L=1,NTV
      LTM=LT-NTV+L-1
  991 TAP(LTM)=TMP(LTM)
  992 SUMBX=0.0
      NTV=0
      SUMBSX=0.0
      TAP(LT)=WD(I,J)
      IF (LT-22) 2992,2663,2662
 2662 LT1=LT-22
      LT=22
 2663 IF (SENSE SWITCH 2) 2664,2669
 2664 WRITE OUTPUT TAPE 1,998,IBM,IFILE,IE,I,IBB,(TAP(L),L=1,LT)
      LMN=LMN+1
      LT=1
S     CLA LT1
S     TZE *92
      DO 2665 L=1,LT1
 2665 TAP(L)=TAP(L+22)
      LT=LT1+1
      LT1=0
      GO TO 92
 2669 LT1=0
      LT=0
 2992 LT=LT+1
   92 NSD(I)=NSD(I)+1
   93 CONTINUE
      GO TO 113
C
C     DIRECT PULSE SWITCHED TO LOW GAIN CHANNEL
C
   94 LT=1
S     CLA LMN
S     TZE *994
```

```
      DO 993 L=1,LMN
      BACKSPACE 1
  993 CONTINUE
      LMN=0
  994 IF (IGAIN-1) 197,197,95
   95 IF (LD(I)-1) 995,197,197
  995 TV = TV/CALN(I+1)
      TTD(I+1)=TTD(I)
      SUMA(I)=9.99
      LD(I)=1
      I=I+1
      LD(I)=1
      IF (ICD-1) 84,84,96
   96 BACKSPACE 7
      ICD=1
      I2=1
      CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
      I1=NS+1
      GO TO 84
C
C     DIRECT PULSE IS TERMINATED
C
   97 I1=NSD(I)-I5+1+I1
      TV=TH
      I5=0
      LT=LT-6
S     TZE *999
  996 IF (SENSE SWITCH 2) 997,999
  997 WRITE OUTPUT TAPE 1,998,IBM,IFILE,IE,I,IBB,(TAP(L),L=1,LT)
      LMN=LMN+1
  998 FORMAT (I3,I1,I3,I1,1XA1,22F5.2)
  999 LT=1
      IRT=IRT+LMN
      LMN1=LMN
      NSD(I)=NSD(I)-4
      NV=NSD(I)
S     CLA LD(I)
S     TZE *98
      SUMA(I)=SUMA(I)*CALN(I)
      SUMS(I)=SUMS(I)*(CALN(I)**2)
      WMAX(I)=WMAX(I)*CALN(I)
S  98 CLA AP(2)
S     TZE *103
      I2=IWPR/(2*MULT)+1-ICD*100
S     TMI *102
      NCA=100
      BACKSPACE 7
      I1=IWPR/2+1
      I2=(IWPR/200)*100+1
      I1=(I1-I2)/MULT+1
      IW4=(IWPR-I2+1)/(MULT*100)
      IREM=((IWPR-I2+1)-(MULT*IW4*100))/MULT
S     CLA IW4
S     TZE *99
S     TRA *100
   99 NCA=IREM
  100 CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
```

```
      ICD=1
      GO TO 104
  102 I1=100+I2
      I2=1
      GO TO 104
  103 NS1=5
  104 I=IM
      NTV=0
      IF (I1-NCA) 105,105,125
C
C     SEARCH FOR START OF BOTTOM PULSE
C
  105 DO 112 J=I1,NCA
      NS1=NS1+1
      IF (WD(I,J)-TV) 107,107,106
  106 NTV=NTV+1
      IF (NTV-10) 112,136,136
  107 NTV=0
  112 CONTINUE
      GO TO 125
C
C     GET MORE DATA FOR DIRECT PULSE
C
  113 I2=I2+(100*MULT)
      I5=NSD(I)
      IF (ICD-IW4) 115,114,180
S 114 CLA IREM
S     TZE *180
      NCA=IREM
  115 BACKSPACE 7
      CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
      ICD=ICD+1
      I1=I
      GO TO 86
C
C     GET MORE DATA IN SEARCH FOR BOTTOM PULSE
C
  125 IF (ICD-IW4) 127,126,184
S 126 CLA IREM
S     TZE *184
      NCA=IREM
  127 I2=I2+(100*MULT)
      I5=NS1-5
      BACKSPACE 7
      CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
      I1=1
      ICD=ICD+1
      GO TO 105
  128 NCA=100
C
C     START OF BOTTOM PULSE IS AT THE END OF PREVIOUS DATA
C
      I2=I2-(100*MULT)
      ICD=ICD-1
      I1=100+I1
      BACKSPACE 7
      CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
```

```
      GO TO 140
C
C     START OF BOTTOM RECEPTION
C
  136 NS1=NS1-10
S     CLA AP(2)
S     TZE *138
      TTB(I)=NS1
      GO TO 139
  138 NTV=AP(1)*PM
      TTB(I)=NS1+NS+NV+NTV
  139 TTB(I)=TTB(I)/PM+AP(2)+X
      I1=I1+NS1-I5-5
S     TMI *128
  140 SUMB(I)=0.0
      SUMBS(I)=0.0
      SUMBX=0.0
      SUMBSX=0.0
      NSB(I)= 0
      NSB2(I)=0
      NSB1=0
      NTV=0
      NUM=1
      BMAX(I)=NV
      NFSD=FAC*BMAX(I)
      BMAX(I)=WD(I,I1)
      ISAVE1=I1
      ISAVE2=I2
      ISAVE3=ICD
      ISAVE4=NCA
      LT=1
      LT1=0
      LMN=0
      SVI(I)=0.0
      SVIX(I)=0.0
      I5=(IWPR-I2+1)/MULT-I1+1
      IF (I5 - NFSD) 141,142,142
  141 NFSD=I5
  142 I5=I1+NFSD-1
      IF (I5-100) 145,144,144
  144 I5=100
  145 NFSD=NFSD+I1-1-I5
      DO 159 J=I1,I5
      IF (WD(I,J)-9.99) 150,175,175
  150 IF (TV-WD(I,J)) 154,151,151
S 151 CLA NUM
S     TZE *152
      SVI(I)=SUMB(I)
      SVIX(I)=SUMBS(I)
      NSB2(I)=NSB(I)
      NUM=0
  152 NTV=1
  153 SUMBX=SUMBX+WD(I,J)
      SUMBSX=SUMBSX+(WD(I,J)**2)
      NSB1=NSB1+1
      TMP(LT)=WD(I,J)
      LT=LT+1
```

```
      GO TO 159
  154 IF (WD(I,J)-BMAX(I)) 156,156,155
  155 BMAX(I)=WD(I,J)
S 156 CLA NTV
S     TZE *158
      NTV=NTV+1
      IF (NTV-5) 153,153,157
  157 NTV=0
      NSB(I)=NSB(I)+NSB1
      SUMB(I)=SUMB(I)+SUMBX
      SUMBS(I)=SUMBS(I)+SUMBSX
S     CLA NSB1
S     TZE *958
      DO 957 L=1,NSB1
      LTM=LT-NSB1+L-1
  957 TAP(LTM)=TMP(LTM)
      NSB1=0
  958 SUMBX=0.0
      SUMBSX=0.0
  158 SUMB(I)=SUMB(I)+WD(I,J)
      SUMBS(I)=SUMBS(I)+(WD(I,J)**2)
      NSB(I)=NSB(I)+1
      TAP(LT)=WD(I,J)
      IBG=1
      IND=22
      LT5=0
 2958 IF (LT-22) 6959,1959,1959
 1959 IF (SENSE SWITCH 2) 2959,8959
 2959 WRITE OUTPUT TAPE 1,998,IBM,IFILE,IE,I,ICC,(TAP(L),L=IBG,IND)
      LMN=LMN+1
      LT=LT-22
      LT5=1
      IBG=IBG+22
      IND=IND+22
      GO TO 2958
S6959 CLA LT5
S     TZE *8959
S     CLA LT
S     TZE *8959
      DO 7959 L=1,LT
      LT1=IND+L-22
 7959 TAP(L)=TAP(LT1)
 8959 LT=LT+1
  159 CONTINUE
C
C     GET MORE DATA FOR BOTTOM RECEPTION
C
S     CLA NFSD
S     TZE *190
      IF (ICD-IW4) 162,161,190
S 161 CLA IREM
S     TZE *190
      NCA=IREM
  162 I2=I2+(100*MULT)
      BACKSPACE 7
      CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
      ICD=ICD+1
```

```
      I1=1
      GO TO 142
C
C     BOTTOM PULSE SWITCHED TO LOW GAIN CHANNEL
C
  175 LT=1
      NSB1=0
S     CLA LMN
S     TZE *2175
      DO 1175 L=1,LMN
      BACKSPACE 1
 1175 CONTINUE
      LMN=0
 2175 IF (IGAIN-1) 197,197,176
  176 IF (LB(I)-1) 177,197,197
  177 LB(I)=1
      TTB(I+1)=TTB(I)
      TV=TV/CALN(I+1)
      I=I+1
      LB(I)=1
      IF (ICD-1) 140,140,178
  178 BACKSPACE 7
      ICD=ISAVE3
      I1=ISAVE1
      I2=ISAVE2
      NCA=ISAVE4
      CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,I2,0)
      GO TO 140
  180 IF (SENSE SWITCH 1) 181,187
  181 PRINT 182,I
      IRT =IRT+LMN
  182 FORMAT (1H0,24HRECORD ENDED FOR CHANNEL,I4,2X39HWITH DIRECT PULSE
     1STILL ABOVE THRESHOLD)
      GO TO 187
  184 IF (SENSE SWITCH 1) 185,187
  185 PRINT 186,I
  186 FORMAT (1H0,24HRECORD ENDED FOR CHANNEL,I4,2X43HWITH NO BOTTOM BOU
     1NCE PULSE ABOVE THRESHOLD)
  187 I=IM
      BMAX(I)=0.0
      SUMB(I)=0.0
      SUMBS(I)=0.0
      SVI(I)=0.0
      SVIX(I)=0.0
      TTB(I)=0.0
      NSB(I)=0
      NSB2(I)=0
      LB(I)=0
      LB(I+1)=0
      LT5=LMN
      LT=1
      NSB1=0
      LMN=0
S     CLA LT5
S     TZE *190
      DO 189 L=1,LT5
  189 BACKSPACE 1
```

```
      IRT=IRT-LT5
C
C     END OF TAPE WORK FOR ONE CHANNEL
C
S 190 CLA LB(I)
S     TZE *194
      SUMB(I)=SUMB(I)*CALN(I)
      SUMBS(I)=SUMBS(I)*(CALN(I)**2)
      SVI(I)=SVI(I)*CALN(I)
      SVIX(I)=SVIX(I)*(CALN(I)**2)
      BMAX(I)=BMAX(I)*CALN(I)
  194 IM=IM+IGAIN
      LT=LT-1-NSB1
S     TZE *9196
      IF (SENSE SWITCH 2) 195,9196
  195 WRITE OUTPUT TAPE 1,998,IBM,IFILE,IE,I,ICC,(TAP(L),L=1,LT)
      LMN=LMN+1
 9196 LT=1
      IRT=IRT+LMN
      NSB1=0
      LMN=0
      LMN1=0
      I2=1
      IW4=ISAVE7
      IREM=ISAVE8
      NCA=ISAVE9
      IF (IM-MULT) 196,196,201
  196 BACKSPACE 7
      GO TO 75
  197 IF (SENSE SWITCH 1) 198,200
  198 PRINT 199,I
  199 FORMAT (1H0,20HVOLTAGES FOR CHANNEL,I4,2X71HHAVE EQUALED OR EXCEED
     1ED THE MAXIMUM VOLTAGE. THIS CHANNEL WAS ABORTED.)
  200 SUMA(IM)=0.0
S     CLA LMN1
S     TZE *194
      DO 9201 L=1,LMN1
 9201 BACKSPACE 1
      IRT=IRT-LMN1
      GO TO 194
C
C     ALL TAPE WORK COMPLETE, PREPARE FOR FINAL COMPUTATIONS
C
  201 I=1
  202 IM=I
S     CLA SUMA(I)
S     TZE *245
      J=LD(I)+LB(I)
      IF (J-1) 220,203,219
  203 J=I+1
S     CLA LD(I)
S     TZE *204
S     TRA *207
  204 NSD(J)=NSD(I)
      TTD(J)=TTD(I)
      SUMA(J)=SUMA(I)
      SUMS(J)=SUMS(I)
```

```
      WMAX(J)=WMAX(I)
      GO TO 219
  207 NSB(J)=NSB(I)
      NSB2(J)=NSB2(I)
      TTB(J)=TTB(I)
      SUMB(J)=SUMB(I)
      SUMBS(J)=SUMBS(I)
      BMAX(J)=BMAX(I)
      SVI(J)=SVI(I)
      SVIX(J)=SVIX(I)
  219 I=I+1
  220 S0=.001
      RANG=SQRTF((S0*TTD(I)*(G/2.0*(YR(I)+YS)+VA))**2-(YR(I)-YS)**2)
      V=VR(I)
      BANG=AANG
  221 CALL CUBIC (BANG,G,RANG,VB,V,VS,ANG)
S     CLA ANG
S     TZE *253
      VX=VB/COSF(ANG)
      S1=S0*VX/(G*3.0)
      S2=S1*(ATANF(SQRTF(VX**2-V**2)/V)-ANG)
      S1=S1*(ATANF(SQRTF(VX**2-VS**2)/VS) -ANG)
      S3=S0*SQRTF(RANG**2+(DR(I)-DS)**2)/3.0
      F3=-.0005*FREQ**2*(S3-S0)
      F3=10.**F3*S0/S3
      RATIO=.0005*FREQ**2*(S1+S2-S3)
      RATIO =((S1+S2)*10.**RATIO)/S3
      RRTD=RATIO*BMAX(I)/WMAX(I)
      RBSDS=RATIO**2*SUMBS(I)/SUMS(I)
      SUMA(I)=SUMA(I)/10.
      AB=NSD(I)
      AD=SUMA(I)/AB
      SUMS(I)=SUMS(I)/(100.*AB)
      SVI(I)=SVI(I)/10.
      SUMB(I)=SUMB(I)/10.
      WMAX(I)=WMAX(I)/10.
      BMAX(I)=BMAX(I)/10.
      TTD(I)=S0*TTD(I)
      TTB(I)=S0*TTB(I)
      AB=NSB(I)
      SUMBS(I)=SUMBS(I)/(100.*AB)
      AB=SUMB(I)/AB
      RBD=RATIO*AB/AD
S     DCT
S     NOP
      SVIX(I)=SVIX(I)/100.
      ANG=90.-ANG*57.2957795
      RANG=S0*RANG/3.0
      IF (SENSE SWITCH 1) 222,230
  222 PRINT 225,IBM,IFILE,IE,I
  225 FORMAT (1H0/1H0,3X12HIBM TAPE NO.,I4,7X8HFILE NO.,I2,7X13HRECEPTIO
     1N NO.,I4,7X11HCHANNEL NO.,I2)
      PRINT 226,WMAX(I),BMAX(I),F3,RRTD
  226 FORMAT (1H0,17HPEAK COMPUTATIONS/5X,11HDIRECT PEAK,7X14HREFLECTED
     1PEAK,6X27HDIRECT PRESS./SOURCE PRESS.,6X16HREFLECTED/DIRECT/6X,F6.
     23,15X,F5.3,17X,E15.8,16X,F6.3)
      PRINT 227,SUMA(I),AD,SVI(I),SUMB(I),AB,RBD
```

```
  227 FORMAT (1H0,20HAVERAGE COMPUTATIONS/5X10HDIRECT SUM,5X14HDIRECT AV
     1ERAGE,5X12HBOTTOM SUM 1,5X16HBOTTOM SUM TOTAL,5X14HBOTTOM AVERAGE,
     25X21HBOTTOM AV./DIRECT AV./6X,F8.3,10X,F5.3,12X,F8.3,11X,F8.3,13X,
     3F6.3,16X,F7.3)
      PRINT 228,SUMS(I),SVIX(I),SUMBS(I),RBSDS
  228 FORMAT (1H0,24HENERGY FLUX COMPUTATIONS/5X21H MEAN SQUARED DIRECT
     1,5X23HSUM OF BOTTOM 1 SQUARED,5X21H MEAN SQUARED BOTTOM ,5X13HBOTT
     2OM/DIRECT/11X,F8.3,19X,F8.3,19X,F8.3,15X,F7.3)
      PRINT 229,ANG,NSB(I),NSD(I),NSB2(I),TTD(I),TTB(I),RANG
  229 FORMAT (1H0,13HMISCELLANEOUS/5X8H90-ALPHA,5X12HBOT. SAMPLES,5X12HD
     1IR. SAMPLES,5X18HFIRST BOT. SAMPLES,5X11HDIR. TRAVEL,5X11HBOT. TRA
     2VEL,5X11HCOMP. RANGE/4X,F6.2,4HDEG.,7X,I4,13X,I4,16X,I4,13X,F7.3,
     34HSEC.,5X,F7.3,4HSEC.,5X,F7.3,4HKYD.)
  230 IF (SENSE SWITCH 2) 231,245
S 231 CLA BMAX(I)
S     TZE *245
      WRITE OUTPUT TAPE 1,232,IBM,IFILE,IE,I,IDD,WMAX(I),BMAX(I),RRTD,
     1       SUMA(I),AD,SVI(I),SUMB(I),AB,RBD,NSB(I),NSD(I),F3
      WRITE OUTPUT TAPE 1,232,IBM,IFILE,IE,I,IEE,SUMS(I),SVIX(I),SUMBS(I
     1),RBSDS,TTD(I),TTB(I),RANG,ANG,DUMMY,NSB2(I)
      IRT=IRT+2
  232 FORMAT (I3,I1,I3,I1,1X,A1,9F9.4,2I4,E15.8)
      M=0
  233 IF (IGAIN-1) 240,240,234
  234 IF (I-2) 235,236,237
  235 AMXA(I+1)=AMXA(I)
      AMNA(I+1)=AMNA(I)
      GO TO 240
  236 AMXA(I-1)=AMXA(I)
      AMNA(I-1)=AMNA(I)
      GO TO 240
  237 IF(I-3) 238,235,236
  238 STOP 1010
S 240 CLA M
S     TNZ *245
      AMXA(I)=MAX1F(AMXA(I),ANG)
      AMNA(I)=MIN1F(AMNA(I),ANG)
      M=1
      GO TO 233
  245 I=IM+IGAIN
      IF (I-MULT) 202,202,246
  246 IM=1
      IF (SENSE SWITCH 1) 250,9997
  250 PRINT 251
  251 FORMAT (1H1)
 9997 IF (SENSE SWITCH 5) 9998,9999
 9998 IDUMP(1)=-3
      IDUMP(2)=+0
      IDUMP(3)=2*IFILE
      IDUMP(4)=-7
      IDUMP(5)=+0
      IDUMP(7)=-1
      IDUMP(8)=+0
      IDUMP(9)=IRT
      CALL DUMP(IDUMP)
 9999 CONTINUE
      IF (IRT-20000) 9095,9090,9090
```

```
9090 PRINT 9091,IRT
9091 FORMAT (1H1/1H0,25HTAPE UNIT 1 IS FULL WITH ,I5,85H RECORDS. CORE
    1WILL BE DUMPED ON TAPE UNIT 5. RESTART WITH A NEW TAPE ON TAPE UNI
    2T 1./1H1)
     WRITE OUTPUT TAPE 1,276,IZZ
     END FILE 1
     REWIND 1
     IRT=0
     GO TO 9998
9095 IF (IE-NRECF) 50,270,270
 252 FORMAT (1H0,14HAPPROX. ANGLE=,F6.2,10X13HRECEPTION NO.,I5)
 253 PRINT 252,BANG,IE
     BANG=BANG+5.0
     IF (BANG-AANG-5.0) 221,221,254
 254 IF (IVT-IRT) 285,245,245
 255 CALL DATSP (7,WD(1,1),0,0,NCA,MULT,5,12,0)
     IF (SENSE SWITCH 1) 256,246
 256 PRINT 259,I
 259 FORMAT (1H0,35HBOTH APERTURES FOR RECEPTION NUMBER,I4,1X45HARE ZER
    1O AND THIS RECEPTION HAS BEEN SKIPPED.)
     GO TO 246
S 270 RTD 7
S    IOD
     IDUMP(6)=IDUMP(6)+1
     IF (SENSE SWITCH 2) 271,1
 271 PRINT 280,IBM,IFILE,IE,MIT,IRT,EVENT,ID3,ID4
     DO 1271 L=1,NH
     M=L+IGAIN-1
     PRINT 3271,L,DR(M),AMXA(M),AMNA(M)
1271 CONTINUE
     DO 1272 L=1,5
     AMXA(L)=0.0
1272 AMNA(L)=90.0
     IF (IFILE-IFT) 1,272,1
 272 PRINT 275,IRT,IFILE
 275 FORMAT (1H1/1H0,14HTHERE ARE NOW ,I5,40H RECORDS ON TAPE UNIT 1 AF
    1TER COMPLETING,I3,22H FILES ON TAPE UNIT 7./1H1)
     PUNCH 14,IRT
     WRITE OUTPUT TAPE 1,276,IZZ
 276 FORMAT (9XA1)
     END FILE 1
     GO TO 1
 280 FORMAT (1H0/1H0/1H0/1H0,9X11HDATRAC TAPE,18X13HMASTER   TAPE/5X3HN
    1O.,2X16HFILE  RECEPTIONS,12X3HNO.,4X13HTOTAL RECORDS/4XI3,5XI1,
    26XI3,14XA5,8XI5/1H0/3X5HEVENT,5X9HID NUMBER/5XA1,7X,2A5/1H0/5X21HH
    3YDROPHONE   DEPTH IN,7X14H90-ALPHA (DEG)/7X6HNUMBER,7X4HFEET,
    48X4HMAX.,8X4HMIN.)
 285 MA=IVT+1
     DO 287 L=MA,IRT
     BACKSPACE 1
 287 CONTINUE
     IRT=IVT
     IM=1
     PRINT 290
 290 FORMAT (1H0/1H0,26HCOMPLETE RECEPTION SKIPPED)
     GO TO 250
3271 FORMAT (10XI1,8XF6.1,6XF6.3,6XF6.3)
END(0,1,1,1,1)
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